The Sidereal Messenger.

CONDUCTED BY WM. W. PAYNE,

Director of Carleton College Observatory.

JANUARY, 1887.

CONTENTS:

Thou Lord in the beginning hast laid the foundation of the earth, and the heavens are the works of thy hands.

ARTICLES:— PAGE.

Photographers *versus* Old Fashioned Astronomers. Professor Ormond Stone... 1
Ten Years' Progress in Astronomy 1876-1886.—The Earth—The Moon—The Sun's Parallax—The Sun and Meteorology—Solar Heat—The Solar Surface and Spots—The Solar Spectrum—The Chromosphere—Eclipses and the Corona—Inferior Planets—Mars—The Asteroids—The Major Planets—Comets—Meteors—Stars—Observatories—Instruments—Literature—Necrology. C. A. YOUNG..... 4

EDITORIAL NOTES:—
Volume VI.—The Motion of the Lunar Apsides, President E. S. HOLDEN.—Comet of Finlay.—Error in List of Nebulæ from the McCormick Observatory.—Tracing the Fixed Stars.—Queries in Recent Letters.—The Occultation of *a Tauri* by Professor Davidson.—Colbert's Mathematical Tables.....41-47

BOOK NOTICES:—
Johnson's Theory and Practice of Surveying, and Gore's Elements of Geodesy, John Wiley and Sons.—Wentworth's Analytic Geometry by Ginn & Company...47-8

The Messenger will be published monthly except for Aug. and September.

Subscription price per year (ten numbers) $2.00.

Communications should be addressed to the Editor, Northfield, Minnesota.

NORTHFIELD, MINN.

CARLETON COLLEGE OBSERVATORY.

Entered at the Post Office at Northfield, Minn., and admitted for transmission through the mails at second-class rates.

XUM

JOHN A. BRASHEAR,

MANUFACTURER OF

Refracting and Silver-glass Reflecting Telescopes,

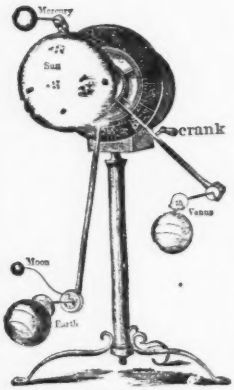
SPECULA, PLANE MIRRORS,

AND

Mirrors for Special Purposes of Speculum Metal or Glass, Parallel Plates, Polarizing and Solid Eye-pieces. Glass and Rock Salt Prisms, Diffraction Grating Plates, Grating Spectroscopes, Telespectroscopes, Heliostats, Driving Clocks, and General Optical Apparatus.

ACCURATE SURFACES OUR SPECIALTY.

ADDRESS, OBSERVATORY AVENUE, ALLEGHANY, PA.



HELIOTELLUS.

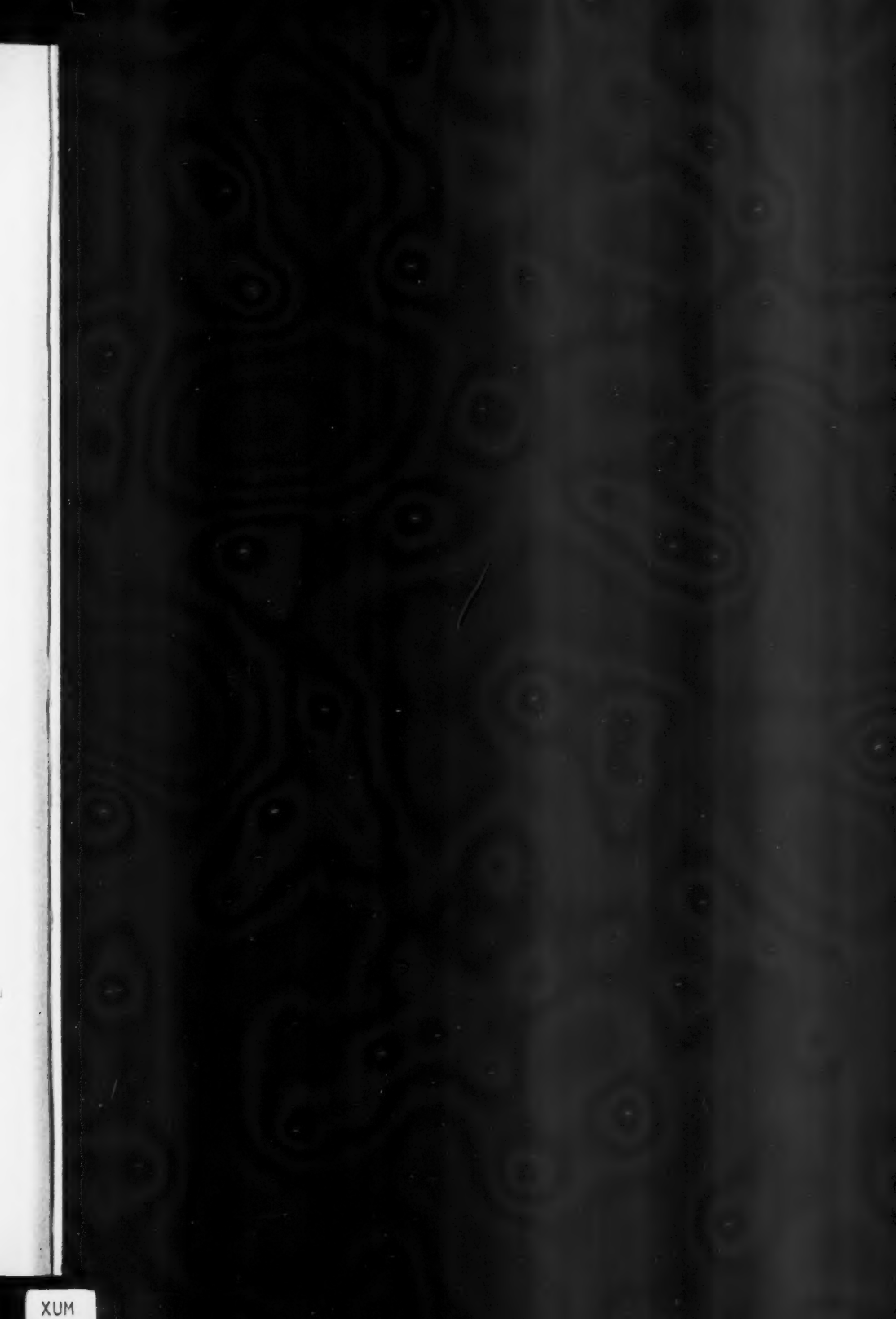
When the Earth's axis is pointed to the north, it will continue so pointing throughout the revolution, and will be in the Ecliptic. The Earth rolls over from west to east, and if the Equator be continued to the sky, it will meet the Equinoctial. So with the Ecliptic, if continued, it will come near to the Moon, near to Mercury, near to Venus, and always to the Sun, for the ecliptic plane.

I have now in my possession all the Heliotelluses for sale, made with a set of tools costing $25,000, which tools were afterwards destroyed by fire. They were so accurately made that the Heliotellus cannot now be duplicated for less than $250 each. The greatest impediment I find in their introduction is the Tellurian, which makes a false showing of the heavenly movements. It is a device in which the Earth's axis wabbles around the zenith and never points to the north. This is the greatest bearier to the comprehension of this most sublime of the sciences. The Heliotellus shows so near the truth that it is not hard to comprehend.

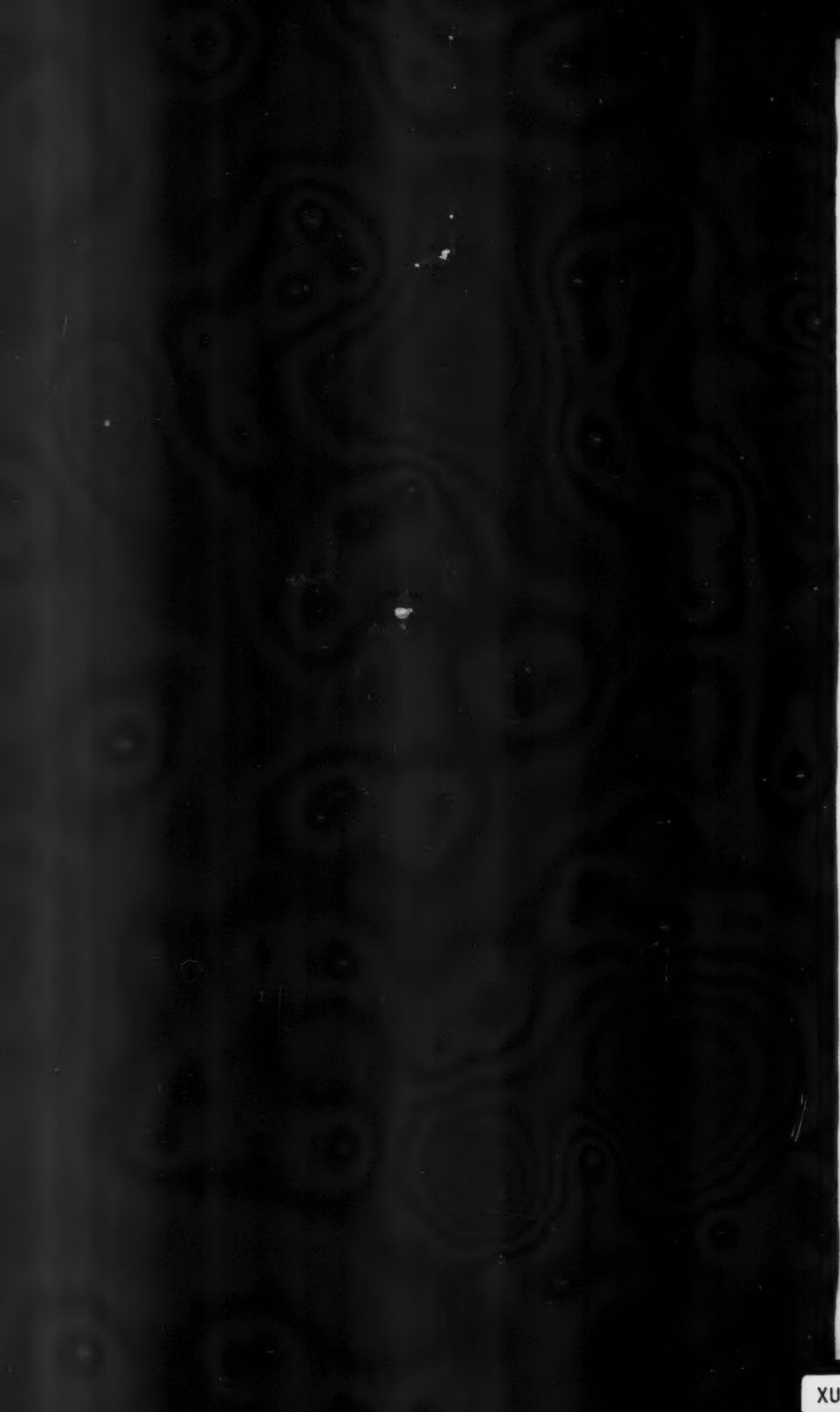
In high schools, seminaries, colleges, and all places of learning we find many globes and maps of the earth, but where can one be found having the Equator of the Earth so constructed that if continued it will meet the Equinoctial in the right place on the sky? Every child should have a truthful understanding of science. The Ecliptic should be correctly understood. All instruments which show imperfect teaching are hurtful; those which teach correctly are useful. The one should be rejected, the other sought for, and when found should be prized even as a "pearl of great price." Three hundred such I now possess, all perfectly made, and I now propose to sell two hundred at the reduced price of $30 each, or for $65, the price of one, I will send four, each well packed in a strong box to carry by express anywhere. Address,

HENRY WHITALL,

BELVIDERE SEMINARY, BELVIDERE, N. J.



XUM


XUM

The Sidereal Messenger,

CONDUCTED BY WM. W. PAYNE,

Director of Carleton College Observatory, Northfield, Minnesota.

VOL. 6, NO. 1. JANUARY, 1887. WHOLE NO. 51.

PHOTOGRAPHERS versus OLD FASHIONED ASTRONOMERS.

ORMOND STONE.*

Professor Holden's article in the *Overland Monthly* for November, entitled, "Photography the Servant of Astronomy," will not simply interest an intelligent public, but is likely to prove of real service to practical astronomers by again calling their attention to the great use which photography promises to offer to astronomy, and that too in the immediate future, and by so doing stimulate them to still greater activity in this important branch of celestial physics.

Celestial photography is making rapid strides, but the subject is yet in its infancy, and is likely to accomplish vastly more than most of us have realized. Professor Holden's resumé is interesting, and gives a comprehensive view of what photography is doing and is likely to do in aid of astronomy.†

I desire, however, to call attention to the impression which must naturally be made upon the ordinary reader by much of what is now written by those interested in celestial photog-

*Director of the Leander McCormick Observatory, University of Virginia, Va.

†One minor subject he does not touch upon, namely, the investigation of the characteristics of optical glass, which, while not strictly a part of astronomy, is a subject so important to every astronomer as to be fitly classed with the other services mentioned by Professor Holden. The characteristics of an object glass can be readily studied by photographing the spectra of stars, and studying the widths of the different portions of these spectra when observed at various positions on each side of the focus of the objective under consideration.

The use of photography for the investigation of the indices of refraction of the ultra violet rays, I have not seen suggested anywhere, though I do not doubt it has been proposed as it might easily have escaped my notice. All that is necessary apparently, is to substitute a camera for the eye in the use of the spectrometer, photographing, at the same time, a plumb line attached to the viewing telescope. The details of the operation will easily suggest themselves to anyone familiar with the use of the goniometer and the camera.

XUM

raphy. One would infer, I think, that there is no longer any use for that venerated, but now to-pass-away, class of individuals hereafter to be known as "old fashioned astronomers," and that hereafter observers skilled in the use of the meridian circle and the micrometer, will bear about the same relation to astronomical photographers as did the astronomers who lived before the invention of the telescope to the Herschels and the Struves of later date.

While welcoming photography as ushering in a new era in the history of the science, it may well be questioned whether the older methods will be altogether discarded. While, no doubt, photography will accomplish much, will it accomplish everything? In fact, cannot many observations be made better without the aid of the camera than with, and will this not be the case for some time to come?

The most important work relating to the structure of the heavens, as perhaps all will agree, is the determination of the accurate positions of the stars. However interesting such experiments may be, it is questionable whether the introduction of a photographic plate instead of the eye will not complicate rather than improve observations made with the meridian circle. In the case of close objects, such as clusters, while the positions of a larger number of objects observed in the field of an equatorial can probably be obtained with a given accuracy in a given time, still it remains to be seen whether the *highest* accuracy is to be obtained by the micrometer with or without the aid of the camera; for after all, it is not a question of doing away with the micrometer, but of making the observations directly at night upon the celestial objects themselves, or afterwards measuring their photographic images, still using the micrometer, though under a different name; nor am I so sanguine that by photography micrometrical measurements will be completely freed from the effects of atmospheric displacement. In the case of double stars, further evidence is needed to show that with a given accuracy a larger number of objects can be observed in the same time with the camera than without, assuming that it requires nearly as much time and

trouble to make a good photograph of a double star as it does to make one of a cluster. As to the new methods not requiring highly skilled observers; if skill is required to properly bisect a double star as seen in the heavens, why will not the same skill be required to bisect its images as observed in the measuring engine?

In regard to the Nebula of Orion, the beautiful photograph of Mr. Common does, without doubt, give the form with an ease and an accuracy which are unattainable by any other known means;* still I am inclined to agree with Professor Holden, "that the figure of the Nebula of Orion has remained the same from 1758 to now; * * * but that in the brightness of its parts undoubted variations have taken place, and that such changes are even now going on;" and it may be taken as an axiom, that any changes in form will be at least accompanied, if not preceded, by changes in brightness. If this be true it is not to photography but to photometry, that we must look for the earliest positive evidence of changes in this the most remarkable nebula in the heavens. The observations of this nebula which were made at this observatory in 1885 were merely tentative in their character and were made without a knowledge of the existence of Mr. Common's photograph. The winter of 1885–86 was a very cloudy one and but few opportunities were obtained for observing it. During the past September and October, however, the nebula was repeatedly examined, not for the purpose of determining the form of the nebula but of determining the relative brightness of the various condensations of which it is composed. The region *A* preceding the trapezium was especially observed, and the brightness of its condensations compared with one another and with other portions of the Huyghenian region. The differences of brightness were esti-

*In some parts of the nebula I am unable to see with our great refractor some of the details there given; in other parts I have recognized details not shown in the photograph, and this remark is not limited to portions concealed by the enlarged images of the brighter stars. In this connection it is interesting to note that the portion of the region *A* just following the star B 589=H 57 is perhaps the *brightest* portion of A, as shown in Mr. Common's photograph; while, as seen here this year, it is one of the *faintest*.

mated in "steps," as was done by Argelander in his observations of variable stars, each condensation being usually compared on the same night both with brighter and with fainter condensations. Such estimates probably give more reliable results than can be obtained with the aid of the camera.

Other cases where the older methods are the better will probably suggest themselves.

The object of this note is, however, not to decry the use of photography for astronomical purposes, but rather to suggest that photography will not necessarily displace every other method of observation, but that much still remains which can be accomplished by an old fashioned astronomer. After all, I take it, Prof. Holden and others who are so forcibly impressed with the utility of photography, do not mean to "ring out the old," but simply to "ring in the new." Then hail to photography, one of astronomy's most useful, but not her only servant.

TEN YEARS' PROGRESS IN ASTROMOMY (1876-1886).*

PROFESSOR C. A. YOUNG.

The Earth.

In what may be called the astronomy of the earth, there is no very great discovery, nothing extremely new and brilliant to record during the past decade; but there has been considerable and steady progress.

As regards the earth's form and dimensions, it has become quite certain that Bessel's ellipticity ($\frac{1}{299}$) is too small. Clarke's value of $\frac{1}{293}$ is now admitted and employed on the U. S. Coast Survey with a decided improvement of accordance. A slightly larger value even is suggested by the most recent pendulum observations, and $\frac{1}{292}$ is now adopted in Europe.

One of the most important steps in this branch of investigation is the discovery, by Mr. Peirce (of our own Coast Survey), of the large correction required in many former pendu-

*Address before the New York Academy of Sciences, delivered May 17, 1886.

lum determinations, on account of the yielding of the stand from which the pendulum is suspended.

During the past ten or fifteen years, a great amount of material has been collected towards a complete gravitational survey of the earth, by the work of Lieut.-Col. Herschel in India, and of the officers of the Coast Survey in this country and elsewhere, and a very important part of it has consisted in connecting the older work with the new, by Peirce's operations in Europe, and those of Herschel in this country.

At the same time it has become increasingly evident that very little is now to be gained by endeavoring to find a spheroid fitting the earth's actual form more closely. It will be best simply to adopt some standard (say that of Clarke, but it makes very little difference what), and to investigate hereafter the local deviations from it. These deviations seem to be larger and more extensive than used to be supposed, the station errors in latitude and longitude being at least quantities of the same order as the variations of elevation.

We mention, in passing, the investigations of Fergola, based on observations at Pulkowa and Greenwich, and leading to a suspicion that the axis of the earth is slightly changing its position and shifting the place of the poles on the earth's surface. Operations have been organized to determine the question, by co-operation between different observatories in nearly the same latitude, but widely differing in longitude.

Nor ought we to pass unnoticed an elaborate paper by Kapteyn, of Groningen, on the determination of latitude by a method depending upon time-observation of stars, at equal altitudes, though in widely different parts of the sky; the stars being so selected that all errors of star-places, instrument, and clock, are almost perfectly eliminated. In the same connection we ought to mention also the new equal-altitude instrument, the Almucantar, invented by Chandler, of Cambridge, and his development of the method of determining time by its use. It may possibly supersede the transit instrument for this purpose, as he seems to expect, though we think it hardly likely.

Rapid progress has been made in determining the difference of longitude between all the principal parts of the earth. There now remain very few stations of much importance, which have not their longitude from Greenwich telegraphically settled within a small fraction of a second. In Europe, Albrecht has combined into a consistent whole all the different data for more than one hundred points. Our American system has been similarly worked out by Schott, and is connected with the European by no less than four different and independent cable-determinations. South America is connected with the United States by the recent operations of our naval officers in the West Indies and along the eastern and western coasts of the continent; and with Europe by a cable connection between Lisbon and Pernambuco, also effected by them. It is worth noting that two large errors in European longitudes owe their detection to American astronomers. The difference of longitude between Greenwich and Paris was corrected by our Coast Survey in 1872 to the extent of nearly half a second of time, and our naval officers in 1878 showed that the then received longitude of Lisbon was 8.54*s* too small! It is a less surprising fact that an error of 35*s* was found in the longitude of Rio.

Our navy has also determined an important series of telegraphic longitudes along the eastern coast of Asia and through the East Indies. The French have been doing similar work in the same regions, especially in connection with the transits of Venus; and the English have determined a large number of longitudes in India. These Asiatic longitudes have been recently connected with Australia and New Zeland by English astronomers, and a telegraphic longitude connection has been effected down the eastern coast of Africa from Aden to the Cape; so that now it is perfectly practicable, if it is desirable, to have one standard of time in all the civilized world.

A word perhaps is here in place as to this question of standard time, and the beginning of the day. The adoption by our railroads of the system of standards differing from Greenwich time only by entire hours has, I think, been admittedly a

great step in advance, as regards public convenience and safety in traveling. At a few points, where standard and local time happen to differ by nearly the maximum possible amount of half an hour, some annoyance is felt and there is still some opposition; but it seems quite clear that, in this country at least, all resistance will soon die out.

As regards the more purely astronomical question of making the astronomical day coincide with the civil day, by beginning at midnight, instead of noon, as it does at present, there is more difference of opinion. For my own part I am frankly in favor of the change, because I see no use in perpetuating an anomaly which is sometimes annoying and confusing. At the same time the change would, of course, involve some inconvenience to computers and night observers, and it must be admitted that at present a large number, and possibly a majority of the most eminent astronomers, in other countries as well as in this, are opposed to it. Those of us whose work falls about as much in the day as in the night, and those, I think, who take a long look ahead, are in favor of the reform; but those whose work is mainly nocturnal, or is based on observations made chiefly at or near the "witching hour," dread the inconvenience of a change of date in the midst of the record, and the risk of confusion in the interpretation of old observations.

The question, however, seems to me not a very important one.

I notice that the visitors of the Royal Observatory have just recommended that the change be introduced into the British Nautical Almanac for 1891.

Before passing to the moon, a word should be added as to the outcome of the most recent investigations regarding the steadiness of the earth's rotation. Some irregularities in the lunar motions have appeared to justify a suspicion, at least, that they might be caused by irregularities in the length of the day. The researches of Newcomb upon ancient eclipses and occultations of stars give results not necessarily inconsistent with this hypothesis, perhaps even slightly in its favor; but his careful examination of the past transits of Mercury contra-indicates it pretty decidedly.

The Moon.

During the past ten years there has been no work upon the lunar theory quite on a level with that of Hansen, Delaunay, Plantamour, and Adams in the years preceding; but the labors of Neison, Hill, and Newcomb well deserve mention. The former especially has carried his approximations to a considerably higher point than any of his predecessors, though not without making a few numerical mistakes, which have been detected and corrected by Hill. The investigation of ancient and mediæval observations of the moon by Newcomb is also a very important work, as showing clearly that the lunar theory is still incomplete, and that it is impossible by any tables yet made to represent accurately the whole series of observations. A value of the secular acceleration, which suits the observations of the last two hundred years, will not fit the Arabian observations made one thousand years ago, nor will it satisfy the eclipse observations of still more ancient date; unless at least the received interpretation of those ancient eclipses be admitted to be wrong, as Prof. Newcomb seems to consider rather probable. From his discussion he derives for the secular acceleration a value of 8.4″ as against the value of 12.1″ deduced by Hansen.

It will be remembered probably by every one present that the *theoretical* value of this quantity is about 6″, and that Ferrel, Adams, Delaunay and others attributed its apparent increase to 12″ to the action of the tides in retarding the earth's rotation and so lengthening the day; if Newcomb's value is correct, this retardation is cut down from 6″ to about to 2.5″.

The study of the moon's surface has been carried on with assiduity, but I do not know that any remarkable results have been reached, though Klein's observation, in 1877, of what he supposed to be a newly-formed crater (Hyginus N.) excited a good deal of interest and discussion for a number of years; and the most eminent selenographers are still divided in opinion on the question.

The publication by the German government of Schmidt's

great map of the moon, in 1878, unquestionably marks an epoch in selenography; and the photographic work of Pritchard, and the heliometric determination of the moon's physical libration by Hartwig, must not pass unnoticed.

Probably, however, the lunar work which has drawn to itself most attention and interest is the investigation of the moon's heat by Lord Rosse and Professor Langley.

The earliest observations of the kind date back now forty years, when Melloni, in 1846, first detected the moon's heat by means of the then newly invented thermopile. But the first really scientific *measurements* are only about fifteen years old, due to Lord Rosse, at Parsonstown, and to Marie Davy, at Paris; and they seemed to show that at the time of full moon we receive from our satellite, not merely *reflected* heat, but warmth *radiated* from the moon's surface; as if this surface were raised to a considerable temperature by the long insolation to which it has been exposed during the preceding fortnight. Lord Rosse estimated the probable temperature of this heated rock to be as high as from 300° to 500° F.

But within the past four or five years this conclusion has been called in question. Observations at Parsonstown, of the rapid diminution of radiation during a lunar eclipse, seem to favor the newer view, that the moon's surface, like that of a lofty mountain-top on the earth, never gets very hot, since the absence of air enables the solar heat to escape nearly as fast as it is received.

Professor Langley's recent and still progressing work upon this subject far excels in delicacy and elaborateness anything done before. At first it seemed to show that the temperature of freezing water was never reached even at the hottest parts of the lunar surface; but the latter observations throw some doubt on the legitimacy of this inference. It is found that the radiation from the moon unquestionably contains a considerable percentage of rays which have a wave-length *longer* than any of the heat rays from melting ice; and this fact has been supposed to make it probable that the moon's surface was colder than the ice. But then, within a few weeks, Pro-

fessor Langley has found the long-waved rays in the radiation from an *electric arc!* So the question still hangs debatable.

The Sun's Parallax.

I think we may say that, during the past ten years, substantial progress has been made with the problem of the solar parallax. The transit of Venus, in 1882, adds whatever value its results may have, to those obtained eight years before; but, on the whole, so far as can be judged from the reductions thus far completed and published, it would seem likely that the outcome of the transit observations will be simply to confirm the results obtained by other methods. It may be that the data obtained from the German heliometer measurements will prove more accordant and decisive than those derived from photographs and from the contact observations; there are flying rumors that they will, but it will be necessary to await the official publication for certain knowledge on this point. If they do not, we shall be obliged, hereafter, to relegate transit observations to a secondary rank, as a means of determining the sun's distance. From the various observations of the two transits, different computers have deduced values of the parallax all the way from 8″.6 to 8″.95, corresponding to a distance ranging from 95,000,000 to 91,500,000 miles.

The case is quite different with the heliometer observations of the opposition of Mars, in 1877, made by Mr. Gill, at Ascension Island. These give in a most definite and apparently authoritative manner a value of 8″.783, and are apparently irreconcilable with any value much greater than 8″.81, or less than 8″.75. So far as can be judged from the number, nature and accordance of the observations, I believe we must accept this as the most trustworthy of the geometrical methods yet employed; though the weight of the result would certainly be increased if it did not depend to such an extent upon the work of a single individual.

The confidence of astronomers in the correctness of this value is greatly fortified by the fact that the most recent and reliable determinations of the velocity of light, made by Mich-

elson and Newcomb, in 1877, 1880, 1881 and 1882, when combined with the Pulkowa constant of aberration determined by Nyren from all the data available up to 1882, give a solar parallax accordant with the preceding, almost to the hundredth of a second—8″.794 as against 8″.783. It is true there are possible theoretical objections to the method; as for instance, that the result may be slightly affected by the motion of the solar system through space. Enough is not known certainly about the constitution of the medium that transmits light through space, to decide all such questions *a priori* and authoritatively; but it is unquestionable that any correction needed on account of such possible causes of error must be very minute.

We believe, therefore, that it is safe to assume pretty confidently, that the solar parallax is about 8″.8 (though probably a trifle less), which makes the sun's mean distance 93,000,000 miles, with an error not likely much to exceed 150,000 miles. A larger value of the parallax (about 8″.85) still holds its ground in the nautical almanacs, and undeniably is nearer the *average* of the results given by *all* the known methods. But none of the other methods seem to us to compete at all in precision with the two whose authority we accept.

The Sun and Meteorology.

The study of the solar surface has been carried on very persistently by Spoerer, in Germany, as well as by others, and a great amount of material has been collected bearing upon the theory and nature of sun-spots, and their periodicity. The extensive series of photographs obtained at Kew, and at Dehra Doon, in India, constitutes almost a continuous record of the solar surface for several years. The relation between this periodicity and terrestrial conditions has been assiduously examined, but on the whole the outcome seems to me to leave this connection as doubtful as it ever was, in most cases at least. While in some parts of the earth it looks as if there were a slight but marked increase of storm and rainfall at the time of sun-spot maximum, the reverse seems to be true in other

countries. In South America, Dr. Gould thinks that he has demonstrated a very perceptible effect of the condition of the sun's surface in modifying the strength and direction of the winds ; but thus far similar investigations elsewhere show no such result. It will evidently be necessary to wait for a longer and more widely extended collection of statistics to settle the question. We do not even know as yet whether we get more or less than the average heat from the sun during the sun-spot maximum.

But I think it may be set down as certain that the condition of the sun's surface exerts, if perhaps a real, yet only a very slight effect upon our earthly meteorology. With terrestrial magnetism the case is markedly and singularly different, and one of the most interesting problems now pressing for solution is the nature of the connection between solar disturbances and magnetic storms.

Solar Heat.

A great deal of labor has been expended upon the study of the sun's heat during the last decade. The investigations that strike me on the whole as most worthy of mention are those of our own Langley and of the Italian Rosetti, whose early death a few months ago is a great loss to science. Secchi and Ericsson, on the one side, had contended for a solar temperature of some millions of degrees, basing their results on Newton's law of cooling ; while on the other, Crova and Violle, from their measures of the solar radiation, reduced according to the so-called law of Dulong and Petit, maintained that the temperature does not much exceed that of many terrestrial furnaces, somewhere from 1,500° to 2,500° C. Rosetti's experiments upon the radiation of the electric arc and other sources of intense heat, showed pretty clearly the inapplicability of Dulong and Petit's law to high temperatures, and indicate a solar temperature not far from 10,000° C., or 18,000° F. But they also make it clear that the limits of uncertainty are still very great.

Professor Langley, by his invention of the bolometer, has been able to investigate separately the amount of energy

transmitted to the earth in the solar rays of every possible wave-length, and to determine the effect of our atmosphere in absorbing each kind of ray. He has shown that the older method of investigating this solar radiation, *in a lump* so to speak, gives fallacious results on account of atmospheric absorption; and that the necessary correction compels us to increase our estimate of the sun's energy at least twenty per cent. In my own little book upon the sun, published in 1881, I had set the so-called solar constant at twenty-five calorics per square metre per minute. It is now certain that it must be put at least as high as thirty. Professor Langley's investigations seem also to show another remarkable fact—that we do not receive from the sun any at all of the low pitched, slowly pulsing waves, such as we get from surfaces at or below the temperature of boiling water. The solar spectrum appears to be cut off abruptly at the lower end; and this cutting off we know cannot have been effected in the earth's atmosphere, because we receive from the moon in considerable quantity just this very sort of low-pitched rays. Langley finds them also abundant in the radiation of the electric arc, so that we can hardly suppose them to be *originally* wanting in the solar heat. It now looks as if we must admit that they have been suppressed either in the atmosphere of the sun itself, or in interplanetary space. Another striking conclusion first clearly pointed out by Langley is that, if the sun's atmosphere were removed, its light would be strongly blue.

The Solar Surface and Spots.

As regards the general make-up of the solar surface, I do not think there has been any new fact of extreme importance brought out within ten years. Janssen has, however, carried solar photography to higher excellence than ever attained before, and has obtained plates that show the "granules" and their grouping on a scale previously unknown. He thinks that his plates prove a peculiar constitution of the solar surface, consisting in collections of clearly defined and rounded granules, separated by regions or streaks where they are ill defined and

elongated ; and he calls the phenomenon the "reseau photospherique," or photospheric network. According to him the "net" remains approximately constant for some minutes at a time, as shown by plates taken in quick succession, but is subject to rapid and enormous changes in periods exceeding a quarter of an hour or so. I find some skepticism among high authorities as to the trustworthiness of his conclusions. There are suggestions that the appearances presented may be due to currents of air in the telescope tube and at the surface of the sensitive plate ; but I am disposed to think he is right, for, on several occasions when the seeing has been exceptionally fine, I have observed with my own eyes something quite analogous in our large telescope at Princeton.

The spots have been carefully studied by several observers, by Spoerer especially, in a statistical way, and by Vogel, Lohse, Tacchini, and others, as to structure and detail. Spoerer has brought out very clearly the connection between the number and average latitude of the spots. It appears that, speaking broadly, the disturbance which produces the sun-spots begins in two belts on each side of the sun's equator in a latitude of over 30°; these belts or spot-zones then gradually move in towards the equator, the sun-spot maximum occurring when their latitude is about 16°; while the disturbance gradually and finally disappears at a latitude of 8° or 10°, some twelve or fourteen years after its first appearance. But two or three years before this disappearance, a new zone of disturbance shows itself in the same latitude as its predecessor, so that for a while, about the time of sun-spot minimum, there are two well-marked zones of spots on each side of the sun's equator; one pair near the equator, due to the expiring disturbance which began some ten or twelve years ago ; the other far from the equator, and due to the newly arising out-burst, which will reach its maximum in three or four years, and then pass away like the former.

There can be no doubt that the phenomenon is a very significant one, but its explanation, like that of the periodicity itself, is still to be found.

Nor is the problem of the spots themselves yet fully solved. Not that there is any reasonable question that they are *hollows* in the solar photosphere; but how they originate, how deep they are, and what are the causes of their darkness, and the condition and temperature of the darkening substance; these are questions to which only uncertain answers can now be given. A long and important series of observations upon the widening of the lines of certain elements in the sun-spot spectra has been made by Mr. Lockyer, and establishes clearly the fact that those lines, of *iron* for instance, which are conspicuously black and wide in the sun-spots, are often just those which do *not* show themselves conspicuously in the prominences; and moreover both in spots and prominences the iron lines that do show themselves are most frequently those which closely coincide with lines in the spectra of other substances. Singularly, also, and so far quite without explanation, it appears according to his observations that at the sun-spot maximum those *iron* lines, which at other times are conspicuous in spot spectra, entirely disappear.

Perhaps I may be allowed to mention here a *recent* observation of my own upon these spot spectra: with a high dispersion the darkest part of the spot spectrum is found to be not continuous, but made up of fine lines overlapping or almost touching each other, with here and there a clear space left, like a fine bright line. It means, I think, that the absorbing vapors which darken the interior of the spot are wholly gaseous, and tend to disprove the idea that they are mostly of the nature of smoke or steam. We mention, also, in passing, another thing which has been shown by our large instrument at Princeton—that the apparently bulbous, finger-tip-like terminations of the penumbral filaments are often, under the best circumstances of vision, resolved into five bright, sharp-pointed hooks which look like the tips of curling flames.

The Solar Spectrum.

In 1877, Dr. Henry Draper, of New York, by a series of most laborious, time-consuming and expensive researches, discov-

ered the presence of oxygen in the sun, evidenced in his photographs, not by fine dark lines, as in the case of elements previously recognized, but by bright, hazy bands. It is difficult to assign any reason why this gas should behave so peculiarly and so differently from others, and for this reason many high authorities are indisposed to accept the discovery. But the evidence of the photographs seems fairly to outweigh any such purely negative theoretical objections.

Other advances have been made in the study of the spectrum, due mainly to the great improvements in spectroscopic apparatus. Until recently it has not been easy to decide with certainty as to some lines in the spectrum whether they were of solar or telluric origin; the great bands known as A and B for instance. It was only in 1883 that the Russian Egoroff succeeded in proving that these are produced by the oxygen in the earth's atmosphere. In his experiments on a scale previously unknown, the light was transmitted through tubes more than sixty feet in length, closed at the end with transparent plates, and filled with condensed gas.

It was quite early pointed out that the sun's rotation ought to produce a shift in the position of lines in the spectrum according as the light is derived from the advancing or receding edge of the solar disc, and Zollner thought he could perceive it. The earliest *measures*, however, were, I believe, those obtained independently by Vogel and the writer in 1876. In the great bisulphide of carbon spectroscope of Thollon, the displacement becomes easy of observation; and very recently Cornu, by taking advantage of it, and by an extremely ingenious arrangement for making a small image of the sun to oscillate across the spectroscope slit two or three times a second, has been able to discriminate at a glance between the telluric and solar lines; the former stand firm and fast, while the latter seem to wave back and forth.

In this connection also should be mentioned the great map of the solar spectrum, for which Thollon received the Lalande prize of the French Academy of Sciences last January, and the still more accurate and important map photographed by

Professor Rowland, by means of his wonderful diffraction gratings, and now in course of publication. Nor would it be just either to omit the earlier and less accurate maps of Fievez and Vogel, which, when published, were as far in advance of anything before them as they are behind the new ones; nor the maps just made by Professor Smyth, of Edinburgh.

It was in connection with the construction of such a map by Mr. Lockyer, that he was led to his theory of the compound nature of the so-called chemical elements, partly as a result of his comparisons of the spectra of different substances with the solar spectrum, and partly in consequence of considerations drawn from certain phenomena observed in the solar and stellar spectra themselves. His first paper on the subject was read late in 1878. This "working hypothesis," as its author calls it, has met with much discussion, favorable and unfavorable. It unquestionably removes many difficulties, and explains many puzzling phenomena; at the same time there are very serious objections to it, and some of the arguments upon which Mr. Lockyer originally laid much stress have turned out unsound. For instance, he made a great point of the fact that, after all precautions are taken to remove impurities, several elementary substances show in their spectra common lines—"basic lines" he called them—indicating, as he thought, a common component. He found in the solar spectrum about seventy of these "basic lines." Now, under the high dispersion of our newer spectroscopes, these lines, which were single to his instruments, almost without exception dissolve into pairs and triplets, and withdraw their support from his theory.

I suppose that at present the weight of scientific opinion is against him; but for one I do not believe his battle is lost. In view of the law of Dulong and Petit, which establishes a relation between the atomic weight and specific heat of bodies, it seems to be pretty certain that *hydrogen* cannot be the elementary "urstoff" out of which all other elements are made by building up, as he at first seemed disposed to maintain; this element stands apparently on no different footing from the rest. But I see no reason why the elements, as we know them,

may not constitute one *class* of bodies by themselves, all built up out of some as yet more elemental substance or substances. The "periodic law" of Mendeljeff suggests such a relation. And our received theories so stumble, hesitate, and falter in their account of many of the simplest phenomena of the solar and stellar atmospheres, that a strong presumption still remains in favor of the new hypothesis. I am not prepared to accept it yet; but certainly not to reject it.

The Chromosphere.

The study of the chromosphere and prominences has been kept up, very systematically and statistically, by Tacchini in Italy, and with less continuity, but still assiduously, by several other observers. I do not know, however, that any new results of much importance have been arrived at. The list of bright lines visible in their spectra has been a good deal enlarged: and Trouvelot thinks he has observed *dark* prominences—objective forms that show, black but active, upon the background of bright scarlet hydrogen in the surrounding chromospheric clouds. It may be that he is right; but so far as I can learn, no other observer of the solar atmosphere has seen anything similar. I certainly have not myself. And I think some of his published observations of velocities of two or three thousand miles a second in the motions of the prominences, as evidenced by the displacement of lines in the spectrum, are still more questionable.

In two or three cases, prominences have been observed since 1876 considerably higher than any known previously. In October, 1878, I myself observed one which attained an elevation of nearly 400,000 miles (13½').

Eclipses and the Corona.

The sun's corona has been perhaps more earnestly studied than anything else about the central luminary, especially during the four elipses which have occurred since 1876. At the eclipse of 1878, in the midst of an epoch of sun-spot quiescence, the corona was found less brilliant than ordinary, and especially

deficient in the unknown gas that produces the so-called 1474 line—the line which characterizes the spectrum of the corona, and first demonstrated conclusively its solar origin in 1869. But while the corona at this time was less brilliant than it had been formerly, it was far more extensive. At least it seemed so; for at Pike's Peak and Creston, Langley and Newcomb were able to follow its streamers to a distance of 6° from the sun. It is possible, however, that this extension was only due to the superior transparency of the mountain air.

The Egyptian eclipse of 1882 gave us some interesting results respecting the spectrum of the prominences and the corona. It appears that the light of the corona is especially rich in the ultra-violet, and in the photographs of the spectrum a number of bands are found which have been interpreted, with questionable correctness, I think, as indicating the presence of carbon. The eclipse of 1883 was observed in the Pacific Ocean by French and American parties, but, I think, added very little real information. Professor Hastings made an observation which he believed to establish a peculiar theory proposed by himself, viz., that the corona is merely a diffraction effect produced by the moon's limb, and depending on the non-continuity of phase in long stretches of light vibrations. With a peculiar apparatus prepared expressly for the purpose, he found that at any moment the 1474 line was visible to a much greater distance from the sun, on the side least deeply covered by the moon, than on the other: as unquestionably would happen if his theory were correct. But the same thing would result from the mere diffusion of light by the air; and, notwithstanding his protests, the French observers who were at the same place, and nearly all others who have discussed the observations, think that this was the true explanation of what he saw. So far as I know, the discussion of the subject which has resulted from his publication has only strengthened the older view—that the corona is a true solar appendage; an intensely luminous but excessively attenuated cloud of mingled gas and fog and dust surrounding the sun, formed and shaped by solar forces.

XUM

The diffraction theory has one advantage—that it relieves us from stretching our conceptions as to the possible attenuation of matter to the extent necessary in order to account for the fact that a comet, itself mostly a mere airy nothing, experiences no perceptible retardation in passing through the coronal regions. There can be no question that this has happened, several times: the last instance having been the great comet of 1882. But on careful consideration it will be found, I think, that our conceptions will bear the stretching without involving the least absurdity; a single molecule to the cubic foot would answer every necessary condition of the luminous phenomenon observed. And all the rifts and streamers, and all the radiating structure and curved details of form, cry out against the diffraction hypothesis. The observations of the eclipse of 1885 (observed only by a few amateurs in New Zealand) have not proved important.

At present the most interesting debate upon the subject centres around the attempt of Mr. Huggins (first in 1883) to obtain photographs of the corona in full sunlight. He succeeded in getting a number of plates showing around the sun certain faint and elusive halo forms which certainly look very coronal. Plans were made and have been carried out, for using a similar apparatus on the Riffelberg, in Switzerland, and at the Cape of Good Hope. But so far nothing has been obtained much in advance of Mr. Huggins' own first results. Since September, 1883, until very recently, the air has been full, as every one knows, of a fine haze, probably dust and vapor from Krakatoa, which has greatly interfered with all such operations. It is now fast clearing away, and I for one am somewhat sanguine that a much greater success will be reached next winter at the Cape, and perhaps even in England during the coming summer.

Just about the same time that Huggins was photographing in England, Professor Wright was experimenting in New Haven in a different way: isolating the blue and ultra-violet rays by the use of colored media, stopping out the sun's disc and receiving the image of the coronal regions on a fluorescent

screen. He also had obtained what he believed, and still believes, to be a real image of the corona, when the aerial haze intervened to put an end to all such operations; for of course it is evident that whether one operates by this method or by photography, success is possible only under conditions of unusual atmospheric transparency and purity.

I suppose at present the predominant feeling among astronomers is that the case is hopeless, and that Huggins and Wright are mistaken. It may be so. But my own impression is that they are probably correct; although, of course, the matter is still in doubt.

Inferior Planets.

Leaving now the sun, and passing to the planetary system, we come first to the subject of intra-Mercurial planets.

The general opinion among astronomers (in which I fully concur) is that the question has been now fairly decided in the negative, *i. e.*, it is practically certain that within the orbit of Mercury there is no planet of a diameter as large as five hundred miles, probably not one hundred. If such a one existed, it could not have failed to be discovered by the wide-angled photographs taken at the eclipses of 1882 and 1883, to say nothing of the visual observations. Of course, it is well known that at the eclipse of 1878 Professor Watson supposed he had discovered two such bodies, and his extensive experience and his high authority, led, for a time, to a pretty general acceptance of his conclusion. I notice that Dr. Ball, even very lately, in his "Study of the Heavens," is still disposed to credit the discovery. But Dr. Peters, by a masterly discussion of the circumstances of the observations themselves, and a comparison with the star maps, has shown that it is almost certain that Watson really saw only the two stars Theta and Zeta Cancri. In the same paper also, Peters examined all the observations of small, dark spots crossing the sun's disc which, up to that date (1879), had been made by Leverrier and others the ground for their belief in "Vulcan;" and he shows that they really afford no sufficient ground for the conclusion. As to Mr. Swift's supposed observation of two objects with large discs "both

pointing to the sun," they certainly were not the two seen by Watson, while they were in the region covered by Watson and several other observers. What the precise nature of the mistake or illusion may have been it is perhaps not now possible to discover, but I think no one, unless perhaps Mr. Swift himself, now considers the observation important.

While, however, the question of a "Vulcan" is now pretty definitely settled, it is not at all impossible, or even improbable, that there may be intra-Mercurial asteroids, and that some of them may be picked up as little stars of the sixth magnitude or smaller, by the photographers at the eclipse of next August, or in 1887. The sensitiveness of our present photographic plate is now many times greater than it was even in 1882.

As to the planet Mercury, there is very little to report. It "transited" the sun in May, 1878, and again in November, 1881, and during the transits numerous measures were made of its diameter, giving results substantially in accord with the older values. I have already alluded, in connection with the earth's rotation, to Newcomb's investigation of former transits of this planet as establishing the sensible uniformity of the earth's rotation.

The planet Venus, by her transit in 1882, has attracted much attention, and much interest is felt as to the final outcome of the whole enormous mass of data, photographic and visual. Just how long we shall have to wait for the publication, seems still uncertain. I have already said, however, that probably these transits will never again be considered as important as hitherto.

The most important physical observations upon the planet during the decade seem to be those of Langley, who, during the transit of 1882, observed a peculiar, and so far unexplained, illumination of one point on the edge of the planet's disc, and those of Trouvelot and Denning, who have observed and figured certain surface markings of the planet. I think I may fairly mention also our Princeton observation of the spectrum of the planet's atmosphere during the transit, and our confir-

mation of Gruithuisen's old observation of a white cap (likely enough an ice-cap), at the edge of the planet's disc—probably marking the planet's pole, and showing that the planet's equator has no such anomalous inclination of 50° or 60°, as stated in some of the current text-books. This cap has also been observed by Trouvelot and Denning. But this lovely planet is most refractory and unsatisfactory as a telescopic object, apparently enveloped in dense clouds which mostly hide the real surface of the globe, and mock us with a meaningless glare.

We mention in passing, but without indorsement, the speculations of Houzeau, who has attempted to account for some of the older observations of a satellite to Venus, by supposing another smaller sister planet, "Neith," circling around the sun in an orbit a little larger than that of Venus, and from time to time coming into conjunction with it. But the theory is certainly untenable; a planet large enough to show phases, as the hypothetical satellite is said to have done, in the feeble telescopes with which many of the observations were made one hundred years ago or more, would be easily visible to the *naked eye even*. There can be little doubt that all the Venus satellites so far observed are simply *ghosts* due to reflections between the lenses of the telescope, or between the cornea of the eye and all eye lens.

Mars.

But while Venus has gained no moons during the past ten years, Mars has acquired two, and they are both native Americans. There is no need to recount the faithful work of Professor Hall with the then new great telescope at Washington and its brilliant result; brilliant in a scientific sense, that is, for regarded as luminaries, it must be admitted that the Martial satellites, in spite of their formidable names of Phobos and Deimos, do not amount to much. Under the best of circumstances, they are too faint to be seen by any but keen eyes at the end of great telescopes. Small as they are, however, the little creatures punctually pursue the orbits which Hall has computed for them, and, when the planet came to its opposi-

tion a few weeks ago, they were found just in their predicted places. They are interesting, too, from the light they throw upon the genesis and evolution of the planetary system, almost compelling the belief that they have come *gradually* into their present relation to the planet. The inner one, Phobos, revolves around the primary in *7h* 39*m*, which is less than one-third of the planet's day. The theory of "tidal evolution," proposed by Professor G. H. Darwin in 1878-80, as the result of his investigations upon the necessary mechanical consequence of the tidal reactions between the earth, sun and moon will account for Phobos, and I know nothing else that will, though, of course, it would be rash to assert that no other account can ever be given.

Much attention has also been paid to the study of the planet's surface. In 1876 we were already in possession of three elaborate maps, by Proctor, Kaiser and Terby, agreeing in the main as to all the characteristic formations. In 1877, Schiaparelli, of Milan, detected, or thought he did, on the planet's surface a numerous system of "canals"—long, straight channels, some of them more than a thousand miles in length, with a pretty uniform width of fifty or sixty miles; and from his observations he constructed a new map, differing from the older ones somewhat seriously, though still accordant in the most essential features. His nomenclature of the seas and continents derived from ancient geography is certainly a great improvement on that of his predecessors, who had affixed to them the names of their friends and acquaintances among living astronomers. There has been some skepticism as to the reality of these "canals"; but in 1879 and 1881 they were all recovered by Schiaparelli, and several other observers, notably Burton, also made them out. Moreover, Terby finds from drawings in his possession that they had before been seen, though not understood or clearly recognized, by Dawes, Secchi, and other observers. At present, the balance of evidence is certainly in their favor, especially as the observers at Nice report seeing them last spring. I do not think the same can be said in respect to another observation of Schiaparelli's on the same ob-

XUM

ject made in 1881. He then found nearly all of these canals—more than twenty of them—to be *double*, *i. e.*, in place of a single canal there were two—parallel and two or three hundred miles apart. No one else so far has confirmed this "gemination" of the canals; but the planet does not come to a really favorable opposition again until 1890 and 1892, when probably the question can be settled.

The time of rotation has during the past year been determined with great accuracy by Bakhuyzen, who has corrected some errors of Kaiser and Proctor, and finds it $24^h\ 37^m\ 22.66^s$. In 1876, there still remained some question as to the amount by which the planet is flattened at the poles. The majority of observers had found a difference between equatorial and polar diameters amounting to between $\frac{1}{160}$ and $\frac{1}{30}$, while, on the other hand, a few of the best observers had found it insensible. The writer in 1879 made a very careful determination, and found it $\frac{1}{212}$, a quantity closely agreeing with the theoretical value deduced by Adams as probable from the motion of the newly-discovered satellites.

The Asteroids.

On May 1st, 1876, the number of known asteroids was 163. To-day it stands at 258, 95 of these little bodies having been discovered within the decade, 45 of them by one man, Palisa, of Vienna, while our own Peters is responsible for 20.

None of the new ones are especially remarkable, *i. e.*, some of the older ones are always more so; the most inclined and most eccentric orbits, the longest and the shortest periods, none of them belonging to any of the late discoveries. One point is noteworthy, that the more recently discovered bodies are much smaller than the earlier ones. The first 25, discovered between May, 1876, and October, 1878, have an average opposition magnitude of 11.2, while the last 25, discovered since April, 1883, average only 12.2; *i. e.*, the first 25 average about 2½ times as bright as the last. Out of the whole 95, two are of the 9th magnitude (one of them, No. 234, was discovered as recently as August, 1883,) 14 are of the 10th, 33 of

the 11th, 33 of the 12th, and 13 of the 13th. Of these last 13, 10 have been found within the past two years ; and of the 12 others found within the same time, 6 are of the 11th magnitude, and 6 of the 12th.

It is clear that there can remain very few to be discovered as large as the 10th magnitude ; but there may be an indefinite number of the smaller sizes.

The Major Planets.

As regards the planet Jupiter, the one interesting feature for the past ten years has been "the great red spot." This is an oval spot, some 30,000 miles in length by 6,000 or 7,000 in width, which first attracted attention in 1878. At first, and for three years, it was very conspicuous, but in 1882 it became rather faint, though still remaining otherwise pretty much unchanged. In 1885 it was partly covered with a central whitish cloud, which threatened to obscure in entirely ; but this season the veiling cloud has diminished, and the marking is again as plain as it was in 1882 or 1883. How long it will continue no one can say ; nor is there any general and authoritative agreement among astronomers as to its nature and cause.

In connection with observations upon this object, several new determinations have been made of the planet's rotation period, and they all show that, as in the case of the sun, the equatorial markings complete the circuit more rapidly than those in higher latitudes ; a white spot near the equator gives $9^h\ 50^m\ .06^s$, as against $9^h\ 55^m\ 36^s$, for the red spot, which is approximately in latitude 30°.

We must not omit to mention Professor Pickering's new photometric method of observing the eclipses of this planet's satellites. Instead of contenting himself with observing merely the moments of their disappearance and reappearance—an observation not susceptible of much accuracy—he makes a series of rapid comparisons between the brightness of the waning or waxing point of light during the two or three minutes of its change, using as the standard one of the neighboring uneclipsed satellites. From these comparisons he determines

the moment when the satellite under eclipse has just half its normal brightness; and this with a probable error hardly exceeding a single second, while the old-fashioned method gave results doubtful by not less than a quarter of a minute. Cornu and Obrecht have independently introduced the same method at Paris. When we have a complete twelve years' series of such observations, they will give an exceedingly precise determination of the time required by light to traverse the earth's orbit, and so, indirectly, of the solar parallax.

As regards Saturn, there is nothing to report so startling as Jupiter's red spot. A white spot, which appeared in 1877, enabled Hall to make a new determination of the rotation period which came out $10^h\ 14^m\ 14^s$. This is in substantial accord with an earlier determination of W. Herschel's ($10^h\ 16^m\ 07^s$), but involves a serious correction of the value $10^h\ 29^m\ 17^s$ given in most of the text-books. The error probably came from a servile copying of a slip of pen made by some book compiler, fifty years ago or more, in accidently writing Herschel's value of the rotation of the inner ring, instead of that of the planet.

Much time has been spent in observations of the rings, and Trouvelot has reported a number of remarkable phenomena, most of which, however, he alone has seen as yet. The most recent micrometric measures have failed to confirm Struve's suspicion that the rings are contracting on the planet. Extensive series of observations have been made upon the satellites by H. Struve, Meyer, and others in Europe, and by Hall in this country. Hall's observations are especially valuable, and the series is now so nearly completed that we may soon hope to have most accurate tables. In the case of Hyperion, there is found a singular instance of a *retrograde* motion of the line of apsides of the orbit, produced by the action of an *outside* body, the effect being due to the near commensurability of the periods of Hyperion and Titan. This most peculiar and paradoxical disturbance first showed itself as an observed fact in Hall's observations; and, soon after, Newcomb gave the mathematical explanation and development. He finds the mass

of Titan to be about $\frac{1}{12500}$ that of Saturn. It may be noted, too, that Hall's observations of the motions of Mimas and Enceladus indicate for the rings a mass less than $\frac{1}{10}$ that deduced by Bessel; instead of being $\frac{1}{100}$ as large as the planet, they cannot be more than $\frac{1}{1000}$, and are probably less than $\frac{1}{10000}$.

The satellites of Uranus have also been assiduously observed at Washington, so that at present the Uranian system is probably as accurately determined as the Jovian, perhaps more so. The form of the planet has been shown to be decidedly elliptical (about 1-14) by observations of Schiaparelli and at Princeton; and the same observers have detected faint belts upon the disc, which have also been seen at Nice, and by the Henrys in Paris. Many of the observations appear to indicate a very paradoxical fact—that the belts, and consequently the planet's equator, are inclined to the orbits of the satellites at a considerable angle. The mathematical investigations of Tisserand appear to demonstrate that, in the case of a planet perceptibly flattened at the poles, satellites near enough to be free from much solar disturbance must revolve nearly in the same plane of the equator; while those more remote, and disturbed more by the sun than by the protuberant equator of the planet, must revolve nearly in the plane of the planet's orbit. Thus the two satellites of Mars, the four satellites of Jupiter, and the seven inner satellites of Saturn, all move nearly in the equatorial plane, while our moon and Japetus move in ecliptical orbits. It is very difficult to believe that the satellites of Uranus, which are certainly not ecliptical and are very near the planet, do not move equatorially. And yet it is unquestionable that most of the observations with sufficently powerful telescopes (my own among them) do seem to indicate pretty decidedly that the planet's equator is inclined as much as 15° or 20° to the orbit plane of the satellites.

As to Neptune, there is nothing new. One or two old observations of the planet have turned up in the revision of old star catalogues, and Hall, of Washington, has made a careful and accurate determination of the orbit of its one satellite, and of the planet's mass; while Maxwell Hall, of Jamaica, has de-

duced a very doubtful value of the planet's rotation from certain photometric observations of its brightness.

There has been some hope that a planet beyond Neptune might be found. Guided by certain slight indications of systematic disturbances in the motion of Neptune, Todd made an extended search for it in 1877–8, using the Washington telescope, and hoping to detect it by its disc, but without results. If such a planet exists, it is likely to appear as a star between the 11th or 13th magnitude, and may be picked up any time by the asteroid-hunters. But its slow motion and the fact that our present charts give but few stars below the 11½ magnitude, will render the recognition difficult.

The indications I have spoken of, and certain others first noted in 1880 by Prof. G. Forbes, and depending upon the behavior of certain periodic comets, furnish pretty strong reasons for believing in its existence, though as yet they fall far short of making it certain.

Comets.

During the past ten years we have been favored with an extraordinary number of comets, and while perhaps no single great step has been made, yet it is certain, I think, that our knowledge of these myterious objects has gained a real and considerable advance.

In 1876, curiously enough, not a single comet appeared; but in 1877 there were 6; in 1878, 3; in 1879, 5; in 1880, 5; in 1881, 8; in 1882, 3; in 1883, 2; in 1884, 3; and in 1885, 6; and so far this year, 3. Forty-four comets in all have been observed during the ten years, six of which were conspicuous objects to the naked eye, and two of them, the great comet of 1881, and the still greater one of 1882, were very remarkable ones.

The first of these will always be memorable as the first comet ever photographed. Dr. Henry Draper photographed both the comet itself and its spectrum; Janssen obtained a picture of the comet, and Huggins of its spectrum.

A number of excellent photographs were obtained of the great comet of 1882, especially by Gill, at the Cape. And it is worth mentioning that in May, 1882, a little comet (not in-

XUM

cluded in the preceding list, because no observations were obtained of it) was caught upon the photographs of the Egyptian eclipse.

Two of the bright comets, Wells' comet of 1881 and the great comet of 1882, approached very close to the sun, and their spectra, as a consequence, became very complex and interesting. A great number of bright lines made their appearance. Sodium was readily and certainly recognized; iron and calcium probably, but not so surely. The evidence as to the nature of the sun's corona, derived from the swift passage of the 1881 comet through the coronal regions, has already been alluded to.

The Pons-Brooks comet of 1883–4 is extremely interesting presenting the first instance (excepting Halley's comet, of course) of one of the Neptunian family of comets returning to perihelion. There are six of these bodies with periods ranging from sixty-eight to seventy years. Halley's comet, the only large one of the group, has made many returns, and is due in 1910. Pons' comet, first observed in 1812, has now returned; Olbers' comet of 1815 is due in 1889, and the three others, all of them small, in 1919–'20 and '22.

I have spoken of them as Neptunian comets, *i. e.*, their presence in our system is known to be due in some way to this planet. The now generally received theory is that they have had their orbits changed from parabolas into their present state by the disturbing action of Neptune. Mr. Proctor has pointed out certain unquestionable, though, I think, inconclusive, objections to this view, and he proposes, as an alternative, the startling and apparently improbable hypothesis, that they have been *ejected* from the planet at some past time by something like volcanic action.

On the whole, however, the most important work relating to comets has been that of the Russian astronomer, Bredichin. He has brought the mechanical and mathematical portion of the theory of comets' tails to a high degree of perfection; following out the lines laid down by Bessel, but improving and correcting Bessel's formulæ, and determining their constants

by a most thorough discussion of all the accurate observations available.

It is hardly possible to doubt any longer that all the facts can be represented on the hypothesis that the tails are composed of minute particles of matter, first driven off by the comet and then repelled by the sun. Bredichin's most interesting result, arrived at in 1878, is that the tails appear to be of three, and only three, distinct types—the long straight streamers which are due to a repulsive acceleration about twelve times as great as the sun's attraction; the second and most ordinary class of broad-curved tails for which the repulsive force ranges between one and two and a half times that of attraction; and finally, the short, stubby brushes which are found in a few cases, and correspond to a repulsive force not more than one-fourth the sun's attraction. Supposing as he does, that the *real* repulsion is the same for each atom, the *apparent* repulsion, or repulsive *acceleration*, would be greater for the lighter atoms and nearly inversely proportional to their molecular weights; and so he concludes that probably tails of the first type are composed of hydrogen, those of the second type of hydro-carbons, like coal gas, and those of the third, of iron and its kindred metals. As to the second type, the spectroscope speaks distinctly in confirmation. Tails of the first and third types are not common, and are usually faint, and since Bredichin's result was announced, there has been no opportunity for spectroscopic verification in their case.

I said his investigations had given a mathematical and mechanical explanation of comets' tails; but the *physical* question as to the nature of the force which causes the observed repulsion, remains unsettled, though I think there is no doubt that general opinion is crystallizing into a settled belief that it is electrical; that the sun is not at the same electric potential as surrounding space, and that, in consequence, semi-conducting masses of pulverulent matter, such as comets seem to be, are subject to powerful electric forces as they approach and recede from the central body. At the same time there are those—Mr. Ranyard, for instance—who forcibly urge that the

XUM

direct action of the solar *heat* might produce a similar repulsive effect by causing rapid evaporation from the front surface of minute particles, charged with gases and vapors, *frozen* by the cold of outer space.

I ought not to dismiss the subject of comets without at least alluding to the numerous unprecedented and interesting phenomena presented by the great comet of 1882: First, its unquestionable relation to, but distinctness from, its predecessors of 1880, 1843, and 1668, the three belonging to one brotherhood, of common origin, and all following nearly the same path around the sun. I call special attention to this point because Miss Clerke, in her new and admirable "History of Astronomy in the Ninteenth Century" (which I hope every one interested in astronomy will read as soon as may be) has, I think, made a mistake regarding it, assigning to the difference between the computed periods of these comets much too great an importance.

The strange elongation of the nucleus of this comet into a string of luminous pearls; the faint, straight-edged beam of light that enveloped and accompanied the comet for some time; and the several detached wisps of attendant nebulosity that were seen by several observers, are all important and novel items of commetary history.

Meteors.

Time will not allow any full discussion of the progress of meteoric astronomy. It must suffice to say that the whole course of things has been to give increased certainty to our newly acquired knowledge of the connection between meteor-swarms and comets, and to make it more than probable that a meteoric-swarm is the result of the disintegration and breaking up of a comet. This seems to be the special lesson of the Bielids, the reappearance of which as a brilliant star shower last November attracted so much attention. In an important paper read before the National Academy of Sciences, last April, Professor Newton pointed out how all the facts connected with the division into two of Biela's comet forty years ago, its sub-

sequent movements and disappearance, and the meteoric showers of 1872, and 1885, and especially the peculiar features of this last shower, all conspire to enforce this doctrine.

I mention, doubtfully, in this same connection the recent supposed discovery by Denning of what are generally alluded to as "long radiants:" systems of meteors, *i. e.*, which for weeks, and even months together, seem nightly to emanate from the same point in the sky. One of these radiants, for instance, the first of half a dozen described by Mr. Denning, is about 1½° north of β Trianguli, and the shower appears to last from July to November, at the rate of perhaps one or two an hour.

If the fact is *real*, it follows inevitably that, disseminated through all the space in which the earth is moving, and has been moving for several years—not less than 1,000,000,000 miles—there are countless meteoroids moving in parallel lines, and with a velocity so great that the earth's orbital motion of nineteen miles a second is absolutely insignificant as compared with theirs. Their speed must be many hundreds of miles per second. This may be true, but I own I am not ready to accept it yet. The observations indicate directly no extraordinary swiftness. Mr. Proctor, whose mind appears at present to be chiefly occupied by the idea that suns and planets are continually bombarding their neighbors (or at least do so at some stage of their existence), ascribes such meteors to the projectile energies of some of the "great" stars. But there is not time to discuss his notion, and it is hardly necessary until it has begun to receive somewhat more extensive acceptance. I am not aware that so far he has any converts to his theory of comets and meteors.

Stars.

Want of time will also prevent any adequate treatment of the recent progress of Stellar astronomy.

Two great works in the determination of star places must, however, be mentioned. One is the nearly completed catalogue of all the northern stars, down to the ninth magnitude, begun almost twenty years ago, under the auspices of the As-

tronomische Gesellschaft, by the co operation of some fifteen different observatories. The observations are now nearly finished, and several of the observatories have already reduced and published their work. A very few years more ought to bring the undertaking to a successful end.

Another similar work, almost, though not quite, as extensive, is the great catalogue of southern stars, made at the observatory of Cordova by our own Dr. Gould and his assistants. He himself, with his own eyes, observed every star of the whole number—nearly 80,000—his assistants reading the circle and making the records: and the whole has been reduced, printed, and published within the space of twelve years—a veritable labor of Hercules, for which, most justly, our National Academy has awarded him the Watson medal. He had already, some years ago, received the gold medal of the English Royal Astronomical Society, for the *Uranometria Argentina*, an enumeration of all the naked-eye stars of the southern hemisphere, with their approximate positions and estimated magnitudes. This, however, was only a sort of preliminary by-play, to pass the time while waiting for the completion of his observatory and meridian circle.

We must mention also the remarkable star-charts made by Dr. Peters, of Hamilton College, of which he has already published and distributed at his own expense about twenty, and more are soon to follow.

But the old-fashioned way of cataloguing and charting the stars is obviously inadequate to the present needs of astronomy, and a new era has begun. While, hereafter, as hitherto, the principal stars, several hundred of them, will be observed even more assiduously and carefully than ever before, with the meridian circle or similar instruments, the photographic plate will supersede the eye for all the rest. It is now easily possible to photograph stars down to the thirteenth or fourteenth magnitude, and to cover a space of $2\frac{1}{2}°$ square on a single plate. The remarkable thirteen and one-half inch instrument constructed by the Henry Brothers, for the Paris observatory, and first brought into use last August, does this perfectly. Instru-

ments very similar, but smaller, lately set up at Harvard College, at the Cape of Good Hope, and at Liverpool, while they do not reach so faint stars, cover more ground at a time.

Negotiations are already under way to secure the co-operation of a number of observatories for a photographic survey of the heavens; and it is probable that, after some preliminary consultation and before very long, it will be actually in progress. According to Struve's estimates, it could be accomplished in about ten or twelve years, even on the Paris scale, by the combined efforts of fourteen or fifteen establishments. Orders have already been given to the Henry Brothers, by Dom Pedro, of Brazil, and Mr. Common, of England, for instruments precisely like the one at Paris. Americans, and New Yorkers especially, may well take a peculiar interest in astronomical photography, since it was at Cambridge, in 1861, that the first star-photographs were ever made, and here in New York, Rutherfurd and Draper were among the earliest and most successful workers; in the observatory above us is now mounted the very instrument with which Rutherfurd made his unrivalled pictures of the moon and his plates of the Pleiades, more than twenty years ago.

During the past ten years, stellar photometry has become almost a new science. Its foundations, indeed, were laid by J. Herschel, Seidel, Wolff, and Zollner, before 1870, and the magnitudes of some two hundred stars had been measured, and the law of atmospheric absorption determined. But the great work of Pickering, at Harvard, in the invention and perfecting of new instruments, and his Harvard photometry, which gives us a careful measurement of the brightness of all the naked-eye stars of the northern hemisphere, marks an epoch. And he is pushing on, and has already well under way the measurement of the 300,000 stars of Argelander's Durchmusterung. Nor must we omit to mention Pritchard, of England, whose name has just been joined with Pickering's by the Royal Astronomical Society, in the bestowal of their gold medal for his wedge-photometer and the photometric work done with it. The Harvard photometry, and the Uranometria Oxoniensis together

will carry down to all time the record of the present brightness of the stars. They will be especially valuable as data for determining changes in stellar brilliancy.

During the past ten years the number of variable stars has risen from about 100 to nearly 150; and our knowledge of their periods and light-curves has been greatly improved. In America, Chandler and Sawyer, of Boston, and Parkhurst, of this city, have done especially faithful work. During the ten years we have had two remarkable "temporary stars," as they are called—first the one which, in November, 1876, in the constellation of Cygnus, blazed up from the ninth magnitude to the second and then slowly faded back to its former brightness, but to a *nebulous* condition, as shown by its spectrum. Then also the one which, last autumn, appeared in the heart of the nebula of Andromeda as of the sixth magnitude (where no star had ever been seen before), slowly dwindled away, and is now beyond the reach of any existing telescope. Perhaps, too, we ought to mention another little ninth magnitude star in Orion's club, which last December rose to the sixth magnitude, and is now fading; it seems likely, however, from its spectrum, that this is only a new variable of long period.

As to star-spectra, a good deal of work has been done in their investigation with the ordinary stellar spectroscopes by the Greenwich Observatories, by Vogel at Potsdam, and by a number of other observers,—work well deserving extended notice if time permitted. But the application of photography to their study, first by Henry Draper in this city, and by Huggins in England, is the important new step. By the liberality of Mrs. Draper, and as a memorial of her husband, his work is to be carried on with the new photographic instrument and method just introduced by Prof. Pickering at Cambridge. He is able to obtain on a single plate the spectra of all the stars down to the eighth magnitude in the group of the Hyades, each spectrum showing under the microscope the characteristic lines quite sufficiently for classification. A different instrument is also to be built with the Draper fund, which will give single star-spectra on a much larger scale and in fuller detail.

During the decade, the stellar parallax has been worked at by a number of observers. Old results have been confirmed or corrected, and the number of stars whose parallax is determined has been more than doubled. The work of Brunnow and Ball in Ireland, of Gill and Elkins at the Cape of Good Hope, and of Hall at Washington, deserves especial mention. A new heliometer of seven inches aperture has been ordered for the Cape observatory, and when it is received, a vigorous attack is planned by co-operation between that observatory and that of Yale College, which possesses the only heliometer in America.

During the ten years, our knowledge of double stars has been greatly extended; several observers, and most eminent among them Burnham, of Chicago, have spent much time as hunters of these objects, and have bagged between one and two thousand of them. Several others, especially Dobereck in England, and Flammarion in France, have devoted attention to the calculation of the orbits of the binaries, so that we have now probably about seventy-five fairly well defined.

In the study of the nebulæ, less has been done. Stephan at Marseilles and Swift at Rochester have discovered many new ones, mostly faint, and Dreyer, of Dublin, has published a supplementary catalogue, which brings Sir J. Herschel's invaluable catalogue pretty well down to date. The studies of Holden upon the great Orion nebula and the so-called "trifid nebula" deserve special mention, as securely establishing the fact that these objects are by no means changeless, even for so short a time as twenty or thirty years; also the discovery of a new nebula in the Pleiades by means of photography.

Observatories.

During the ten years, a considerable number of new observatories have been founded. Abroad we mention as most important the observatories for astronomical physics at Potsdam, in Prussia, and at Meudon, in France, also the Bischoffsheim observatory at Nice and its succursal in Algiers. The great observatory at Strasburg can hardly be said to have been

founded within the period indicated, but the new buildings and new instruments and new efficiency date since 1880. We ought not to pass unnoticed the smaller observatory at Natal, in South Africa, and the private establishments of von Konkoly at O-Gyalla, of Gothard at Hereny (both in Hungary), and of the unpronounceable gentleman Jedrzejewicz at Plonsk, in Poland, and the observatory at Mount Ætna, from which, however, we have no results as yet.

In the United States we have the public observatories at Madison, Wis., at Rochester, N. Y., and at the University of Virginia, and the, as yet, unfinished Lick Observatory in California; also a host of minor observatories connected with institutions of learning, and mainly designed for purposes of instruction; such establishments have been founded within ten years at Princeton, at Northfield, Minn., at South Hadley, Ms., at Beloit, at Marietta, at Depauw, at Nashville, and at St. Louis, also at Franklin and Marshall College, and at Doane College, in Nebraska; at Columbia College, Ann Arbor and Madison, Wis., and at one or two other institutions which escape me for the moment. Several others are also at this moment in process of erection. Every one of them has a telescope from six to thirteen inches aperture, with accessory apparatus sufficient, in the hands of an astronomer, for useful scientific work.

Instruments.

A large number of new instruments of great power have been constructed. We mention the great thirty-inch refractor of Pulkowa, the twenty-six-inch of Charlottesville, and the twenty-three-inch at Princeton, for all which the lenses were made by our own Clark. We add the great Vienna twenty-seven-inch telescope by Grubb, and the twenty-nine-inch object glass by the Henrys, made for the Nice observatory but not yet mounted; also the nineteen-inch telescope at Strasburg by Merz. Grubb has also at present a twenty-eight-inch object glass under way for the Greenwich observatory, and Clark has nearly completed the monstrous thirty-six-inch lens for the Lick observatory. There never was a decade before

when such an advance in optical power has been made.

Great *reflectors* have been scarce, the only ones of much importance constructed during the time being the twenty-inch instrument at Algiers, and Mr. Common's exquisite three-foot telescope, which he has lately sold to Mr. Crossly in order to make way for one of five feet diameter now, I believe, under construction. The old three-feet and six-feet instruments of Lord Rosse have been improved in various ways, and are still in use—especially in work upon lunar heat. Among newly *invented* instruments we mention the meridian photometer of Pickering, the wedge photometer of Pritchard, the almucantar of Chandler, the concave diffraction grating of Rowland, and the bolometer of Langley—all but one American. Repsold's improvements in the micrometer, in the heliometer, and in the mounting of equatorials should also be mentioned here.

As to new astronomical methods, enough has been already said about photometry and astronomical photography. It is plain that we are entering upon a new era.

Literature.

Astronomical literature has flourished. Among the books of the past ten years, important in one way or another, I mention in the first rank the great work of Oppolzer upon orbit calculation, Gylden's "Astronomy," and the papers of Tisserand, Neison, Darwin, Adams, Hall and Newcomb, on numerous subjects. Among the popular books on general astronomy we have Newcomb's "Popular Astronomy," Ball's "Story of the Heavens," Kaiser's "Sterrenhemel," Fayes' "Origine de la Monde," and Miss Clerke's admirable "History of Astronomy in the Nineteenth Century." More special popular treatises are Nasmyth's and Neison's books upon the moon, Lockyer's "Solar Physics," and my own little book upon the sun, Ledger,s "Sun, Moon and Planets," Gledhill's and Flammarion's books on double and binary stars, and Terby's "Areographie." Of course, it is possible to mention only a few, and I name those which, in one way or another, have attracted for some

reason my special attention, leaving doubtless many others just as valuable unreferred to.

A few new astronomical periodicals have sprung up. In England, *The Observatory* was founded in 1877, and has become an established and very valuable publication.

Copernicus was a still more important and elevated journal, but did not appeal to so large a circle of readers, and, I am sorry to say died only three years old.

In France, the *Bulletin de l'Astronomie*, recently established, is extremely valuable, and I trust will be able to maintain itself. Less importance attaches to Flammarion's *l'Astronomie* which, however, I presume, has many more readers. *Ciel et Terre* is a new astronomical magazine published at Brussels.

In the United States, we have but one distinctively astronomical journal, the SIDEREAL MESSENGER, published by the energetic young director of the Carleton College Observatory in Minnesota. It is interesting and, in many ways, excellent, but in some respects not yet quite up to the standard of American astronomy. There is room and need among us for an astronomical journal of high mathematical character ; but its financial success would be questionable.

Necrology.

The ten years have stricken from the roll of astronomers a few illustrious names, and many of honorable rank. Leverrier, the greatest of them all, died in 1877, and Secchi in 1878 ; Lamont and Maclear in 1879 ; Peters, the vetern editor of the *Astronomische Nachrichten*, Lassel, Dembowski, Pierce and Watson were taken in 1880. Bruhns died in 1881. In 1882 we lost Zoellner, Plantamour, Challis, and Henry Draper. Villarceau died in 1883, Klinkerfues and Schmidt in 1884, and last year Webb, the author of that *vade mecum* of all amateur astronomers, the "Celestial Objects for Common Telescopes."

It would probably be invidious and unwise to attempt to designate precisely those of our younger astronomers who are to succeed to the eminence of those we have lost. It will be easier to prophesy after the fact. But one cannot go wrong

in saying that among the astronomical names which have either first appeared, or have first become conspicuous, during the past decade, we ought to mention, in our own country, Pickering, Holden, Langley, Stone, Burnham, Boss, Chandler, Pritchett, Todd, Paul, Payne, and Elkin. In Europe, we have Gill, Darwin, Common, Gledhill, Tisserand, Vogel, Palisa, Hasselberg, H. and L. Struve, Hartwig, Valentine, and Von Konkoly. And there are many others, both here and abroad, hardly, if at all, their inferiors.

In this rapid, though, I fear, tedious review, I have tried to put before you a just and fairly proportioned sketch of the progress that has actually been made. While no great discovery like that of gravitation appears upon the record, yet I am inclined to think that, with one or two exceptions (during the life of Galileo and Newton), no other decade in all the history of our unselfish science can make a better showing.

As an American, too, I have been surprised and delighted to find how honorable a place our American astronomers hold in the record. Take out of the ten years' story the works of Hall and Newcomb and Gould, of Draper, Langley and Pickering, of Burnham, and Holden, and Stone, and the loss would indeed be grievous.

EDITORIAL NOTES.

Our Happy New Year greeting to all readers, old and new! Though much is in mind, we will be pardoned if we say little this time, in order that we may give as a whole, at once, Professor C. A. Young's excellent review of the progress of astronomy during the last ten years.

This journal begins its sixth volume with more encouragement and a brighter hope for the future than ever before; and still its management is pleased to ask all who think it has merit, to call the attention of their friends interested in astronomy to it. Its size and value shall be enhanced as its list of subscribers is increased.

An article of unusual interest, entitled *The Motion of the Lunar Apsides*, by E. Colbert, of Chicago, is already in type for our our next issue. Some of its analytical features will attract the attention of mathematical astronomers.

President Holden, of the University of California and Director of the Lick Observatory, has recently visited Messrs. Warner & Swasey, of Cleveland, Ohio, who have the contract to mount the great 36-inch refractor for the observatory and to build its mammoth dome.

Comet of Finlay.—This comet seems to trouble the mathematicians more than it does the observers. In A. N., No. 2,754, Professor Brunnow expresses the opinion that it is probably identical with that of de Vico, 1844, I, the orbit of which he himself computed at that time, making its period about 5.47 years. If the two comets are identical, he thinks it probable that the above-named period was wrongly obtained in consequence of great changes going on in the form of the comet during the time of observation. With a period of 5.5 years there could be no planetary disturbance outside of the year 1885, and the present early perihelion passage would seem to make even that period impossible. If a period of 5.26 years were assumed the disturbance of Jupiter in 1873 would be taken into account, but a less period than this would be necessary to account for its appearance in 1844, on the supposition of eight revolutions in the meantime. When Professor Brunnow communicated his views to A. N., Professor Boss had published neither of his two orbits of this comet which have since appeared. The inclination and period of the first were respectively 2° 50′ and 4.32 years; of the second, 3° 1′ and 6.5 years. Computation by ordinary methods, with ordinary data, where the inclination of the orbit is small, makes the period uncertain. Elements by Dr. Krueger in *Observatory* are nearly the same as those given last above. Rev. G. M. Searle has also computed an orbit on the supposition of a period of 5.278 years, the average of eight revolutions since 1844, without planetary disturbance,

XUM

and finds elements fairly in accord with others. Professor Boss thinks the period cannot be less than six years, and that probably the comet has made seven revolutions instead of eight since 1844. It was in the constellation of *Pisces*, December 31, and one degree south of the equator, moving northeast. Though slowly growing faint, it will be visible in the telescope possibly until February.

List of Nebulæ from the McCormick Observatory.—In our catalogue of nebulæ, published in the Astronomical Journal, No. 146, it was found, after our copy had gone to press, that No. 6 was identical with Swift's nebula No. 2, catalogue No. 4. No. 146 was also found to be G. C. 998. Its right ascension in the General Catalogue is probably *2m* too small, that given in the note as brought up from C. H. being right. Swift No. 83, catalogue No. 4, appears to be identical with G. C. 6040.

University of Virginia, Nov. 30, 1886. ORMOND STONE.

Tracing the Fixed Stars.—Professor Elias Colbert, of Chicago, former Superintendent of Dearborn Observatory, has done real service for teachers and students of elementary astronomy, in preparing a little book entitled "The Fixed Stars; Maps for Out-Door Study," published by George Sherwood, of Chicago. This little book is an easy introduction to the study of the heavens, in showing only the most prominent stars in their relative positions, arranged in groups according to the common divisions of the sky called constellations. Its twelve full page maps give all the stars, down to the fifth magnitude, and also a few stars belonging to the fifth magnitude.

The stars of the several groups are connected by right lines so as to distinguish groups, and no attempt is made to reproduce the ordinary figures of the star map. The stars given are properly designated by letters and symbols as they appear in standard star-charts.

We do not know of a more condensed and convenient little hand-book of the stars than this for the student, teacher or prac-

tical observer, in much of the work that requires quick identification of prominent stars. Get a copy and trim it to the size of the pocket and carry it for naked-eye observations, as some astronomers have been doing for years.

Colbert's Mathematical Tables.—Not long ago Messrs. George Sherwood & Co., of Chicago, published a little book of 32 pages, entitled "Mathematical Tables to Four Places and a Fraction," by Professor E. Colbert. It contains trigonometrical formulæ, common logarithms to 1900, logarithms for sums and differences, degrees and time, logarithms for circular functions, natural sines, tangents etc., circle and parabola, 90° to 180°, time in very eccentric orbits, interpolation by differences, construction of logarithms, and useful numbers with logarithms. The aim of this little book is to supply, in compact form, the means of working with four place logarithms, so that the fourth figure in the result may be generally depended on as accurate. One unusual feature is noticed. A symbol like the apostrophe following the last figure of a logarithm in the table means that the fifth figure in the result would be nearly five. If the symbol be inverted, the meaning is that the given tabular value is too great by nearly five in the fifth place. We have used these tables with special satisfaction.

Queries in Recent Letters.—1. What will be the cost of the great Lick refractor when completed?

Ans. The cost of the object glass will be about $50,000, the mounting, $51,000.

2. What is the velocity of light according to Professor Newcomb's recent investigations?

Ans. The velocity of light in vacuo = 299,860 ± 30 kilometers, (see Astronomical Papers, Vol. 2, Pt. 3), which equals in miles, per second, 186,324 ± 19.

The following is a list of recent determinations of the velocity of light, by several prominent physicists:

Michaelson, at Naval Academy in 1879, 299,910 k. m.

Michaelson, at Cleveland, 1882, 299,853 k. m.

Newcomb, at Washington, 1882, 299,860 k. m.
Newcomb, including all determinations, 299,810 k. m.
Foucault, at Paris, in 1862, 298,000 k. m.
Cornu, at Paris, in 1874, 298,500 k. m.
Cornu, at Paris, in 1878, 300,400 k. m.
Listing's discussion of last, 299,990, k. m.
Young and Forbes, 1880-81, 301,382 k. m.

Assuming the velocity of light to be 299860 k. m. and the earth's equatorial radius 6378.2 k. m. (Clark), Professor Newcomb deduces the following values for the solar parallax for varying values of the constant of aberration represented by k :

k.	Dist. in millions of kilometers.	Solar Parallax.
20.42″	149.08	8.825″
.44	149.23	8.816
.46	149.37	8.808
.48	149.52	8.799
.50	149.66	8.790
.52	149.81	8.782
.54	149.96	8.773

The solar parallax corresponding to Nyren's value of k (20.492″) is 8.794″.

The Occultation of a Tauri.—The following is an abstract of a communication to the California Academy of Sciences :

The atmosphere was clear and moderately steady with light flecks of clouds that disappeared before immersion. The star showed signs of unsteadiness, but the moon's bright limb appeared reasonably sharp. The color of the star contrasted well with that of the moon. The moon was one day past the full but the star was visible to the unassisted eye to within four minutes of the time of immersion. As seen in the telescope it did not disappear when it touched the apparent border of the moon, but appeared to move upon the disc until it was fully one and one half times its minute disc on the moon, when it disappeared with the instantaniety of such phenomena. It grew somewhat difficult to see after it had entered upon the moon's disc, but its reddish hue left no doubt to the observers.

at the larger telescopes. It was certainly three seconds of time from the time of the star being at the border and the time of disappearance. In the small telescope G. F. D. lost the star when it touched the moon's limb.

The following are the observed local sidereal times of the observations:

Immersion at the bright limb of the moon,—

Observers, G. D.=23*h* 22*m* 50.73*s*.

C. B. H.=23*h* 22*m* 50.70*s*.

Emersion at the dark limb of the moon,—

G. D. =00*h* 18*m* 59.10*s*.

C. B. H.=00*h* 18*m* 59.27*s*.

The moon being one day past the full there was a narrow, dark edge of the moon where the star reappeared, which it did with the suddenness and brightness indicating no gradual emergence.

At the Chabot Observatory, at Oakland, Mr. Charles Burchhalter, using the eight inch Clark equatorial observed the immersion and emersion at the following local sidereal times:

Immersion,—

C. B.=23*h* 23*m* 28.8*s*.

Emersion,—

C. B.=00*h* 19*m* 45.5*s*.

The conditions attending his observation of the immersion were nearly the same as those already mentioned, but the star apparently did not advance so far on the moon's disc, and in his telescope some of the rays of the star projected outside the moon's limb.

Prof. Davidson then explained a similar circumstance that exhibited itself when he observed the occultation of α Scorpii at the bright limb of the moon in daylight, as far back as 1848 when Prof. Bache failed to elicit from him any explanation of the phenomenon. A second occultation of α Scorpii was referred to a having been made at the bright limb during his work in Puget Sound, with almost identical phenomena. But subsequent experience in observing occultations, eclipses, etc., and in continuous work in goedetic observations convinced him

that the peculiarity mentioned, the Baily's beads of total solar eclipses, the ligament and the black drop of the transits of Venus and Mercury, and similar phenomena, depended wholly and solely upon the unsteadiness of our atmosphere arising from the irregularities of refraction through strata of abnormal temperatures causing objects to exhibit spurious discs. With these convictions and his experience at great elevations he has for many years urged the occupation of high mountain peaks for astrophysical research and observation.

The following are the geograghical positions of the observation stations :

Davidson Observatory, Latitude 37° 47′ 24.75″ north.
Longitude 122° 25′ 40.5″ west.
Chabot Observatory, Latitude 37° 48′ 05.0″ north.
Longitude 122° 16′ 34.4″ west.

The observers, G. D.=George Davidson, C. B. H.=Chas. B. Hill, G. F. D.=G. Fauntleroy Davidson. The immersion was observed with two three inch Iraunhofers, power 105; emersion by Hill, same; by Davidson 6.4 inch Equatorial, Clark, power 150.

GEORGE DAVIDSON.

BOOK NOTICES.

Johnson, J. B.: The Theory and Practice of Surveying, pp. 683, 9½x6½. New York, John Wiley & Sons.

Prof. Johnson is the teacher of Civil Engineering at Washington University, St. Louis, and has been employed on both the U. S. Lake and Mississippi River surveys. The book is intended to give a modern and scientific treatment of the subjects of most value to American surveyors, special emphasis being put on directions for field-work. Book I containing 171 pages is devoted to the description of over twenty different instruments, with directions for their adjustment, and exercises in their use. Book II treats of the ordinary topics of Land, Railroad and Mining Surveying, and also contains valuable chapters on Topographical, Hydrographic, City and Geodetic Surveying. Railroad Surveying is very inadequately treated in a dozen pages. The chapter on Geodetic Surveying is necessarily very elementary, and is confined chiefly to field opera-

tions. Some of the tables at the end of the book are well printed, but the table of four-place logarithms of natural numbers, and the logarithmic traverse table are to be read with a magnifying glass; the tables of trigonometric functions are trying to the eye, and should have occupied twice as much space. A teacher of surveying, who is not a civil engineer, will find in this book much useful and interesting information.

Gore, J. H.: Elements of Geodesy, pp. 282, 9½x6½. New York, John Wiley & Sons.

This work is not intended as a handbook for the professional geodesist. Its aim is to give teachers and advanced students a clear idea of the observations and measurements made in a geodetic triangulation and their reduction by the method of Least Squares. In addition there is a historic sketch of geodetic operations, and a short discussion of the figure of the earth, which is prefaced by a chapter on the development of the formulas for latitudes, longitudes, and azimuths. At the end of each chapter is given a list of books bearing on the subject of the chapter. Some may think that the author has been excessively simple in his derivation of formulæ, but the busy reader can forgive that. It is the opinion of the reviewer that both author and publisher have done their work exceptionally well, and that the book fills its niche admirably.

Elements of Analytic Geometry. By G. A. Wentworth, A. M., Professor of Mathematics in Phillips Exeter Academy. Boston: Messrs. Ginn & Company, publishers, 1886.

Like other books in the Wentworth series of Mathematics, this is written by a teacher who evidently knows the needs of a beginner in analytic geometry. The author has not tried to produce either a treatise or a reference book in this most interesting theme of the pure mathematics, but he has presented in a plain, direct and logical way the essentials for elemental study for a judicious start in independent thinking without the aid of the calculus. He has had a definite object in mind, and he has accomplished it well. The usual topics are presented with a variety of exercises under each aptly chosen to illustrate the principles and fix them in the mind. That the student, on first sight, may recognize the important formulæ, they appear in different type. This new book sustains the well-earned credit of the series in which the publisher's handsome work forms no small part.

R. S. ALLEN,

MANUFACTURER OF

Refracting Astronomical Telescopes,

OF ALL SIZES.

ALT. AZIMUTH OR EQUATORIAL MOUNTINGS,

OBJECTIVES, EYE-PIECES, PRISMS AND ACCESSORIES

Manufactured and Furnished at Short Notice.

No. 136 WESTMINSTER STREET, PROVIDENCE, R. I.

The Movable Planisphere,

By HENRY WHITALL.

The Movable Planisphere of the Heavens is so graduated that every minute, when brought over any day, will show the visible Heavens, the sun and stars in their place, rising, setting, or in any part of the sky, all in one grand whole, not divided into parts, so difficult to patch together. None of the planets are marked, but an accompanying rule and the Almanac locate any one, or the moon, when by a prominent star, tell its name as well as when either will be together, so fully explained that most any child can with this key unlock the mystery of the changing sky; being to astronomy what a map is to geography, or as a directory to the starry heavens, every minute, every day.

Two in a set, sent by mail, to any address, on receipt of $6.00.

Address: HENRY WHITALL,
Belvidere Seminary, Belvidere, N. J.

CARLETON COLLEGE,

NORTHFIELD, MINNESOTA.

Full Preparatory and Collegiate Departments.

English, Scientific, Literary and Musical Courses.

All Departments Open to Students of Either Sex.

Expenses Very Low.

CALENDAR FOR 1886-7.

Winter Term begins Wednesday, January 5th, and ends March 17th, 1887.
Term Examinations, March 16th and 17th, 1887.
Spring Term begins Wednesday March 30th, and ends June 16th, 1887.
Term Examinations, June 14th and 15th, 1887.
Examinations to enter College, September 7th, 1886, June 11th and 13th, and September 6th, 1887.
Anniversary Exercises, June 12th 16th, 1887.
Wednesday, September 7th, 1887. Fall Term begins.

JAMES W. STRONG, President, NORTHFIELD, MINN.

THE COSMOSPHERE.

"PRIMARY PHENOMENAL ASTRONOMY,"

By Prof. F. H. Bailey, A. M., inventor of the Cosmosphere, illustrated above, half covered; and of the Astral Lantern. The work is an able presentation of a very novel method of teaching Astronomy. It is written in an interesting style, and presents much that is novel besides the method of teaching advocated. It is attracting the attention not only of astronomers but of a wide range of scholars.

Northville, Wayne Co., Mich., Jan. 1886. 12 mo: paper, 104 pp. Mailing price, 25 cts.

For Sale. A first-class Astronomical Object Glass 5¼ inch clear aperture, 78-inch focal length, with 3 eye pieces,—1 Sun glass and 1 Venus glass. Price $190.00

D. APPEL,
413 Woodland Ave., Cleveland, Ohio.

For Sale Cheap. A new 8 day Tower Clock striking the hours on a 100 pound bell, compensated pendulum, remontoire escapement 3 foot dial, ready to be put up. FAUTH & CO.,
Washington, D. C.

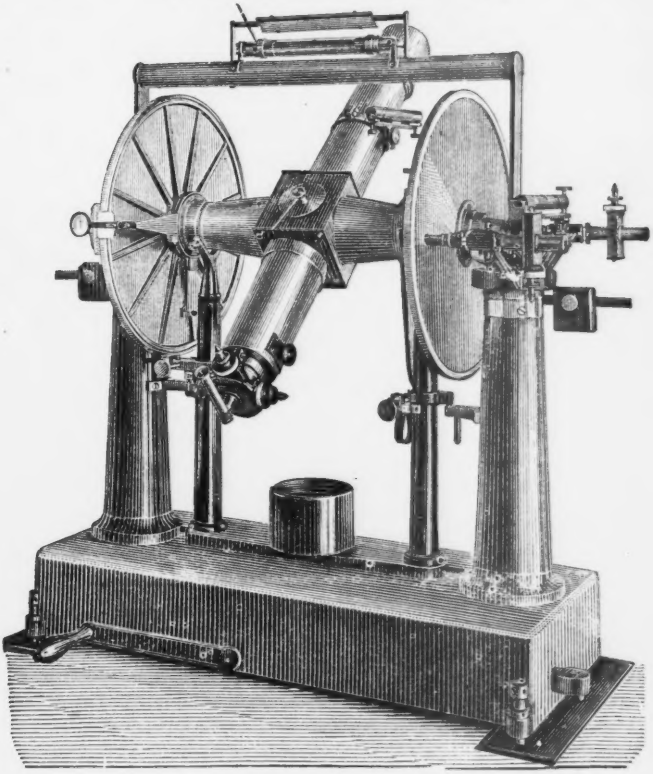
Telescope for Sale. Sextant, 8 inches radius, graduated on silver and reading to 10 seconds. Reliable Instrument. Will be sold very cheap. For particulars, address M. S. DOWLING, LESLIE, MICH.

XUM

FAUTH & CO.,

ASTRONOMICAL WORKS,

WASHINGTON, D. C.



TRANSIT CIRCLE.—4 inch objective. 16 inch circles.

Equatorials, Transits, Meridian Circles, Astronomical Clocks,

WITH BREAK-CIRCUIT ARRANGEMENT.

CHRONOGRAPHS,

Level Vials reading to single seconds, Eyepieces of all kinds, Micronometers, Spectroscopes, and Astronomical outfits of every kind. Also all kinds of instruments for higher Geodesy and Egineering purposes.

☞ **SEND FOR NEW CATALOGUE.** ☜

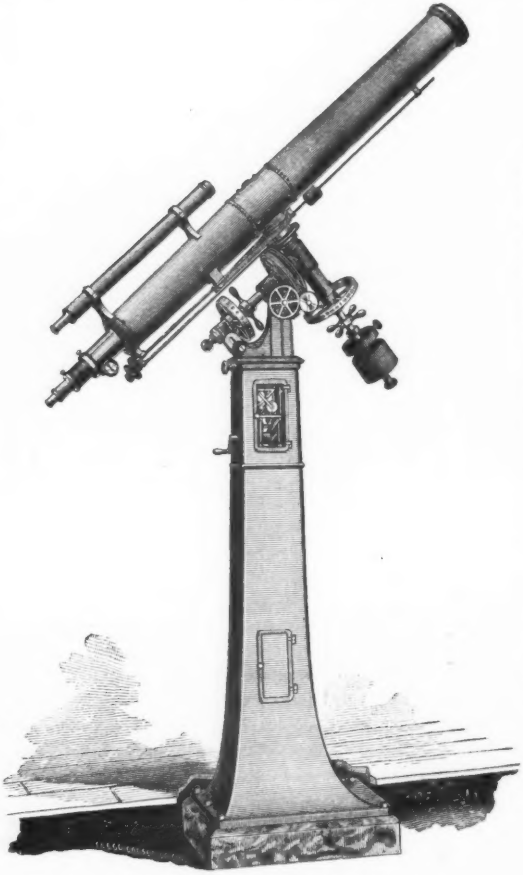
XUM

WARNER & SWASEY,

MANUFACTURERS OF

OBSERVATORY OUTFITS.

TRANSIT INSTRUMENTS, CHRONOGRAPHS, &c.



OBSERVATORY DOMES OF ALL SIZES.

With Patent Frictionless Mechanism for RUNNING GEAR and SHUTTER.

6-INCH EQUATORIAL.

EQUATORIAL TELESCOPES,

From 6-inch aperture to the largest size.

WARNER & SWASEY, CLEVELAND, OHIO, U. S. A.